STUDIES ON THE INFLUENCE OF SOME EDAPHIC GROWTH FACTORS ON THE DISTRIBUTION OF VARIOUS FOREST VEGETATION IN NORWAY

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Since man began utilizing the forest in some way or other, the fact that the distribution of various tree species and types of ground cover vegetation is influenced by soil conditions has been known. To develop a more well-founded knowledge about these correlations, however, was not possible till the subjects botany and soil science had reached a certain degree of maturity. These questions have been treated in almost innumerable scientific publications by botanists and soil scientists. This literature may be grouped, in a somewhat schematic way, as follows: 1. floristic and phytogeographical investigations, 2. studies of forest types and similar works of plant-sociological character, 3. soil investigations aiming at elucidating the soil-forming effects of the vegetation. In forest literature of a more practical character also such questions have often been dealt with. In forest planting, for instance, it is important that the right tree species are chosen, and the evaluation of the soil conditions of the site will thus naturally have its place in the planning work.

Since 1954, a systematic registration of the soil conditions in the Norwegian forests have been carried out. The material, which I have collected in this way, in collaboration with the National Forest Survey enables to a certain extent the elucidation of some aspects of the complex of problems concerning relations between the soil properties and the distribution of various tree species and types of ground cover vegetation. Before examples of results from these investigations are presented, however, attention should be drawn to

the fact that the main aim of the forest survey has not been to attempt to determine the influence of soil factors on the distribution of various types of forest vegetation. The main features of the working method were established before registration of soil conditions was included in the field work of the National Forest Survey. Only elementary soil investigations have been sought fitted into this working program.

Not all comparisons that it might be of actual interest to try, have been made so far, due to the soil registrations being carried out for only some of the forest counties of Norway. When larger areas with fairly uniform climatic and geological conditions have been investigated, it is intended to carry out new comparisons.

In spite of all these reservations, however, it is still possible to obtain from the existing material a certain basis for the elucidation of interesting questions. It is for instance a strong point that we here have a very large numerical material. In all we have compared the results from more than 60,000 sample plots, systematically distributed in the productive forests of 7 of our 18 rural counties. The registrations have been completed for the counties Vest-Agder, Aust-Agder, Telemark, Östfold, Akershus, Hedmark, and Sør-Trøndelag. In addition to the continuous publication of these results (see Låg 1961c, with references) the material has been used in connection with special analyses (see e.g. Låg, 1958, 1959, 1961a, and 1961b).

In these investigations the forest has been grouped according to tree species as follows:

Forest of Norway spruce.

Forest of Scots pine.

Mixed coniferous forest.

Other types of mixed forest of coniferous and broad-leaved trees.

Broad-leaved forest.

The broad-leaved forest is partly subdivided into oak forest, birch forest, aspen forest, and other types of broad-leaved forest.

The ground cover vegetation has been divided into the following

types :

Forest ground rich in grasses and herbs.
Forest ground rich in mosses and with some herbs.
Forest ground rich in *Deschampsia flexuosa.*
Forest ground rich in *Vaccinium myrtillus* with *Dryopteris.*
Forest ground rich in *Vaccinium myrtillus* without *Dryopteris.*
Forest ground rich in *Vaccinium vitis-idaea.*
Forest ground rich in *Calluna vulgaris.*
Forest ground rich in lichens.
Water-logged forest ground.
Forest without ground cover vegetation (forest litter only).

The first nine vegetational types are further divided into two sub-groups according as *Sphagnum* is present or not.

First a short discussion on the influence of the total depth of the soil material on the distribution of tree species and different types of ground cover vegetation. The major part of the soil material was deposited under the last deglaciation. Hence the depth of the soil material is as a rule a primary character of the site. One should, therefore, be fairly safe in saying that we here have to do with the effect of the edaphic factors on the vegetation. In other cases there are, as is well known, interactions between the soil properties and the plants.

In these investigations the soil material has been divided into three depth classes, 0-20 cm, 20-70 cm, and over 70 cm. Looking first at the distribution of tree species, we find that the forest of Scots pine shows a marked tendency to be over-represented on the most shallow soils. If the areas in which the coarse-grained river deposits play a major role are left out, the forest of Norway spruce is over-represented on soil material exceeding 70 cm in depth.

The distribution of forest soils of different depths in the seven counties investigated will be seen from Table 1.

TABLE 1.

Distribution of sample plots in productive forest on soils of varying depths.

County	% of sample plots with soil depths			Total No. of sample plots
	0-20 cm	20-70 cm	over 70 cm	
Vest-Agder	24.6	59.0	16.4	2 947
Aust-Agder	27.3	52.2	20.5	5 203
Telemark	16.2	38.3	45.5	12 275
Östfold	28.8	35.5	35.7	5 061
Akershus	18.5	39.4	42.1	7 222
Hedmark	2.9	16.9	80.2	27 007
Sør-Trøndelag	10.2	48.3	41.5	6 111

Tree species in the coniferous forest extending towards the high mountains form an interesting forest-botanical and phytogeographical problem. In Norway the timber line for conifers is in some districts formed by spruce and in others by pine. The possible causes of these differences have been studied for a long time. If the birch forest is included, the total length of the timber line in the mountainous areas in Norway are, according to rough calculations, estimated at no less than 47 000 km. Today we have going on soil registrations in some alpine forest districts, but, preliminarily it looks as if the explanation of these characteristic differences in the distribution of the tree species most likely should be sought in climatic differences.

The three vegetational types, forest ground rich in grasses and herbs, forest ground rich in mosses and with some herbs, and forest ground rich in *Vaccinium myrtillus* with *Dryopteris* are relatively

far more common on deep than on shallow soils. Forest ground rich in *Vaccinium vitis-idaea*, forest ground rich in *Calluna vulgaris*, and forest ground rich in lichens are comparatively more frequent on shallow than on deep soils. In districts with a great deal of coarse-grained water-sediments, forest ground with lichens will also be comparatively well represented on some deep soils. Thus we find two different main types of forest ground rich in lichens, one on distinctly shallow soils (depth class 0-20 cm) and one on coarse-grained, deep soils (depth class over 70 cm).

The vegetational type, forest ground rich in *Vaccinium myrtillus* without *Dryopteris* appears in many districts to be especially common on soils in the medium depth class. In other regions this vegetational type has a relatively even distribution throughout the three depth classes. The types, forest ground rich in *Deschampsia flexuosa* and forest ground with litter only show no particular correlation with soil depths.

Water-logged forest ground stands in some measure in a class by itself. A surplus of water will lead to an accumulation of humus, and hence to increasing thickness of the soil material. This type will accordingly, as a rule, be overrepresented on deep soils. From a botanical point of view, this group is very heterogeneous.

The gradient of the soil surface is also of importance for the distribution of tree species and vegetational types. In the investigations of the Norwegian forests, the gradient was classified according to the following scale:

0 – 10%, 10 – 20%, 20 – 33%, 33 – 50%, over 50%.

The areas with gradients exceeding 50% are of course small, even in a country as precipitous as Norway. In one of the counties the last two classes were combined.

Roughly, increasing gradient is followed by increasing frequency of forest of Norway spruce, and of the vegetational types forest ground rich in grasses and herbs, forest ground rich in mosses and with some herbs, and forest ground rich in *Vaccinium myrtillus* with

Dryopteris. Simplifying matters somewhat, we can thus say that the more demanding plant species and plant communities seem to a considerable degree to react in a similar way to increasing gradient and to increasing soil depth.

In some districts there is also a tendency that intermediate vegetational types—as forest ground rich in *Vaccinium myrtillus* without *Dryopteris*—show an increasing frequency with increasing gradient on shallow soils, but a decreasing frequency with increasing gradient on deep soils. Using other words one might say that the type forest ground rich in *Vaccinium myrtillus* without *Dryopteris* seems to be "exacting" with regard to gradient for shallow soils, and "modest" for deep soils. Competition and site requirements for the different plant communities should be taken into account when it is sought to explain such relations. It is conceivable that the type forest ground rich in *Vaccinium myrtillus* without *Dryopteris* might have better chances of competing on the most shallow soils when the gradient increases, while it is more apt to lose in the competition with the more demanding plant communities at increasing gradient on deep soils. It will, however, take long before a general view of these complicated problems is attained.

The mineralogical and mechanical composition of the soil material, hydrologic conditions, and a number of other important properties are also in some ways related to the formation of the surface deposits, but will not be discussed in the present paper. We shall, however, take a look at the relationship between the distribution of different tree species and vegetational types, on the one hand, and the thickness of the humus layer and the profile type, on the other hand. It should in this connection be realized that it is more difficult to account for causal connections because of the existence of a mutual state of dependence between vegetation and soil properties.

In the registrations carried out in recent years, the thickness of the humus layer has been classified according to the following scale :

0-3 cm, 3-6 cm, 6-10 cm, 10-30 cm, over 30 cm.

The vegetational types forest ground rich in grasses and herbs and forest ground rich in mosses and with some herbs are as a rule most common on soils with a comparatively thin humus cover. The limit of the humus layer is set at a loss on ignition of 15%. This thickness may at times be hard to indicate exactly for some of the most favorable humus types.

If we compare the two vegetational types that have *Vaccinium myrtillus*, it seems that the humus cover generally is a little thicker where *Dryopteris* is absent than where it is present. There seems to be reason for assuming that a comparatively thin humus layer in such cases is associated with relatively good possibilities for decomposition of the organic matter.

However, the humus cover may also be thin because the production of organic matter is low. This explanation seems natural when we find that e.g. forest ground rich in *Vaccinium vitis-idaea* and forest ground rich in lichens, generally speaking, has a relatively thin humus layer.

In comparing the subgroups with *Sphagnum* with those without *Sphagnum*, within each individual vegetational type, we find, as was to be expected, that the humus cover in general has the greatest thickness where *Sphagnum* occurs.

Water-logged forest ground is of course in the main associated with a relatively thick humus cover.

The soils are divided according to the formation of profiles, into the following groups :

Brown earth.

Transitions brown earth-podzol.

Podzol with thickness of A_2-layer 0-3 cm.
" " " " " 3-6 cm.
" " " " " 6-10 cm.
" " " " " over 10 cm.

Swamp soils.

The classifications used may appear very schematic. The choice of scale is related to the working method employed in these field investigations.

Forests of Norway spruce and broad-leaved forests are relatively common on brown earth, while forests of Scots pine to a greater extent belong to podzol. The birch zone extending up towards the high mountains has not been included in these registrations. In this broad-leaved forest the podzol soils are dominant.

There is a more marked relationship between profile type and ground cover vegetation than between profile type and tree species (Låg 1959). A large part of the brown earth areas have forest ground rich in grasses and herbs and forest ground rich in mosses and with some herbs. Forest ground rich in *Vaccinium myrtillus* with *Dryopteris*, a very common vegetational type, is also relatively well represented on brown earth.

Forest ground rich in *Vaccinium vitis-idaea*, forest ground rich in *Calluna vulgaris*, and forest ground rich in lichens are almost exclusively associated with podzol.

In evaluating relations between soils and tree species and ground cover vegetation, respectively, it should of course be realized that there is also dependence between tree species and vegetational type.

There is also a close relationship between soil conditions and the increment of the productive forest. A few examples will illustrate this. In the Agder counties, where the bedrock consists of Precambrian rocks, and where the soil material is exceptionally scanty, the average, annual normal production per hectare was found to be 5.03 cu.m, 3.61 cu.m, and 2.26 cu.m for soil material $>$ 70 cm, 20-70 cm, and $<$ 20 cm deep, respectively. In Hedmark county which has bedrock relatively well covered with soil material (see Table 1), the normal production averages 6.68 cu.m, 4.96 cu.m, 4.34 cu.m, 3.96 cu.m, 3.65 cu.m, 3.29 cu.m, and 3.07 cu.m. on brown earth, transition types of brown earth - podzol, podzol with an A_2-layer of $<$ 3 cm, podzol with an A_2-layer of 3-6 cm, podzol with

an A_2-layer of 6-10 cm, podzol with an A_2-layer of $>$ 10 cm, and swamp soils, respectively.

One of the aims of forest soil science is to try to explain the effects of the different soil factors on the forest vegetation. The more reliable the interpretations we find, the easier it should be to arrive at the most rational type of silviculture. When, for economic purposes it is desired to interfere with nature, the chances of doing this in the best way are greatest if we know as much as possible about the laws governing the natural conditions.

SUMMARY

An account is given of some results from soil investigations conducted in collaboration with the National Forest Survey in Norway.

The soil material was grouped according to depth into the classes $<$ 20 cm, 20-70 cm, and $>$ 70 cm. Leaving out the smaller areas with deep, coarse-grained water-sediments in terraces along the rivers, we find that the forest of Scots pine tends to be over-represented on shallow soils and that the forest of Norway spruce does the same on deep soils. The three types of ground cover vegetation, forest ground rich in grasses and herbs, forest ground rich in mosses and with some herbs, and forest ground rich in *Vaccinium myrtillus* with *Dryopteris* are especially common on deep soils, while the types forest ground rich in *Calluna vulgaris*, forest ground rich in *Vaccinium vitis-idaea*, and forest ground rich in lichens are relatively best represented on shallow soils.

The frequency of forest of Norway spruce and of the vegetational types forest ground rich in grasses and herbs, forest ground rich in mosses and with some herbs, and forest ground rich in *Vaccinium myrtillus* with *Dryopteris* increases on the whole with increasing gradient. The same three vegetational types are associated with a relatively thin humus cover. If *Sphagnum* patches are found in the bottom layer, the thickness of humus layer is generally increased for

all vegetational types.

Broad-leaved forest and forest of Norway spruce are common on brown earth, while forest of Scots pine is to a greater extent associated with podzol. There is, however, a more distinct relationship between ground cover vegetation and profile type than between tree species and profile type. Forest ground rich in *Vaccinium vitis-idaea*, forest ground rich in *Calluna vulgaris*, and forest ground rich in lichens are practically speaking associated with podzol alone, while forest ground rich in grasses and herbs, forest ground rich in mosses and with some herbs, and partly forest ground rich in *Vaccinium myrtillus* with *Dryopteris*, are relatively common on brown earth.

Examples are given of productivity of soil material of different depths and soils with different development of profiles.

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